VOLUME 79 SEPARATE No. 345

PROCEEDINGS

AMERICAN SOCIETY
OF
CIVIL ENGINEERS

NOVEMBER, 1953

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

FABRICATION AND CONSTRUCTION OF STRUCTURAL STEEL FOR BUILDINGS

by C. L. Kreidler

STRUCTURAL DIVISION

{Discussion open until March 1, 1954}

Headquarters of the Society
33 W. 39th St.
New York 18, N. Y.

PRICE $0.50 PER COPY

THIS PAPER

--represents an effort by the Society to deliver technical data direct from the author to the reader with the greatest possible speed. To this end, it has had none of the usual editing required in more formal publication procedures.

Readers are invited to submit discussion applying to current papers. For this paper the final date on which a discussion should reach the Manager of Technical Publications appears on the front cover.

Those who are planning papers or discussions for "Proceedings" will expedite Division and Committee action measurably by first studying "Publication Procedure for Technical Papers" (Proceedings — Separate No. 290). For free copies of this Separate—describing style, content, and format—address the Manager, Technical Publications, ASCE.

This paper was published at 1745 S. State Street, Ann Arbor, Mich., by the American Society of Civil Engineers. Editorial and General Offices are at 33 West Thirty-ninth Street, New York 18, N. Y.

FABRICATION AND CONSTRUCTION OF STRUCTURAL STEEL FOR BUILDINGS

C. L. Kreidler, Chief Structural Engineer
Lehigh Structural Steel Co., Allentown, Penna.

This Centennial commemorates an event which has added to the benefit of mankind — the founding of the American Society of Civil Engineers. Within a month the 81st anniversary of a disaster will be noted here in Chicago. On October 8, 1871 the Chicago Fire was started in a barn on Dekoven Street not far from Canal. In 48 hours fire destroyed $192,000,000 worth of property out of a total property evaluation of $575,000,000 and 100,000 were homeless.

To architects and engineers the fire meant either a total catastrophe or an opportunity such as all history could not show. Their success is attested today by scores of beautiful and useful buildings, representing the largest concentration of first-rate commerical architecture in the world. In the two decades following the fire $316,220,000 worth of new buildings was constructed in Chicago and forced upon the designers the necessity of developing a new form and technique of building.

With the advent of the elevator, commerce demanded buildings of greater height. The fact that the thickness of a masonry bearing wall increases in direct proportion to its height places a restriction on the height of the building. Consequently, ten stories is about the limit for a building with masonry bearing walls. The appropriately named Monadnock Building here in Chicago at 53 West Jackson Boulevard is reported to be the highest masonry building ever constructed, 16 stories high and rests on walls 72" thick at the base.

In 1885, the Home Insurance Building at the southwest corner of LaSalle and Adams Streets was completed. This was the first truly skeletal building. The frame consisted of serial column-and-beam construction, made up of round cast-iron columns wrought iron box columns of built-up section, and wrought-iron I-beams. Lintels and mullions were cast iron. The building was originally 10 stories high, two stories were added in 1890, and in 1931 the structure was demolished. The outermost floor beams carried not only their portion of the floor load but also one bay of the exterior wall, up to the beam next above. This method of carrying the outer envelope remains the standard practice for tall steel framed structures. Without this technique the skyscraper would be impossible.

In addition to originating the steel frame structure the Chicago school is credited with creating hollow tile fireproofing and expert handling of large glass areas in walls. These features are standard today in modern construction and provide much of the business for structural steel companies.

Each structural steel company has a different organization method for estimating, bidding contracts, preparing shop drawings and fabrication. All of the companies strive to eliminate duplication of work and unnecessary departments with the objective of fabricating at minimum costs to meet competition.

The smaller companies operate one plant and a general office which performs all the functions of the business. The larger companies operate several plants and various offices. Whether the company is large or small the functions may be classified into twelve departments.

The contracting department submits bids and takes contracts. The engineering department prepares designs, makes estimates of weights and costs and supervises the work of the Plant Engineers. The drafting department requisitions the materials to perform the contract and prepares the working drawings. The operating department performs the various operations specified on the shop drawings. The auditing department renders invoices to the customers and compiles data of cost and accounts. The purchasing department buys all materials and supplies for the company. The treasury department approves the credits of prospective customers, collects bills, pays any indebtedness and disburses the salaries and wages of employees. The erecting department maintains the erection equipment and erects the fabricated structural steel in the field. The mechanical engineering department deals with all problems pertaining to the fuel, power and machinery of the plant. The traffic department issues instructions for the routing of all shipments, furnishes instructions for shipping clearances, investigates shipping rates and adjusts all claims with shippers. The personal and public relations department handles relations with the public and welfare matters of the employees. Finally, but a very important department, is the safety department. The functions of this department do not require description but its work is of paramount importance in operating an efficient plant.

The first step toward securing structural steel contracts consists of preparing bids. From plans and specifications prepared by Architects and Engineers and selected by the Contracting Department, an estimate of cost is prepared by the Engineering Department. The majority of contracts are taken on a unit price or lump sum basis. Both types of estimates are composed of the same elements. The cost of the raw material, cost of the direct shop labor, general expenses of operating the shop, and the drawing cost with overhead expenses must be estimated. To these costs are added shipping charges, insurance, taxes and miscellaneous items to arrive at an estimated cost.

To the estimated cost the Contracting Department adds a margin and submits a proposal to the customer giving selling price and delivery date. Frequently, the time of delivery may determine the successful bidder.

When a contract is awarded, the designs, specifications and pertinent information are released to the Drafting Department for the preparation of the shop working detail drawings. Good designs, specifications and complete information without subsequent revisions are the ideal conditions for making detail drawings quickly and economically with the least chance for errors. Permit me to emphasize that prerequisite by repeating. Good designs, specifications and complete information without subsequent revisions are the ideal conditions for making detail drawings quickly and economically with the least chance for errors.

A structural steel structure is similar to a gigantic skeleton-like jig-saw puzzle. However, the Drafting Department must devise an identifying system for each piece so that the Erection Department will be informed how and where to place each element of the structure. At the out-set, the types of connections, the location of shop and field joints, the connection medium — bolts, rivets or welds — and the sequence of erection must be determined. All material that goes into the completed structure must be requisitioned from the Purchasing Department by the Drafting Department. The Drafting Department prepares Preliminary Bills of Material for the use of the Purchasing Department.

Each piece of main material is ordered from the rolling mill to exact size. In these times of quotos, priorities and extended mill deliveries it is imperative that material be ordered promptly in order to keep the fabrication shop

operating and to meet erection schedules. Now, if into this system we inject a series of design changes, you can appreciate the trying situation which develops.

From the design drawings, the Drafting Department prepares a Framing Plan which is very similar to the design drawing except that typical connections and identifying markings are added. This drawing is diagrammatic to a small scale such as Figure #1. - Second Floor Plan of Unit #1 of the Jordan Marsh store in Boston, Mass. With the Plan serving to identify the pieces, column details — Figure #2., and Beam Details — Figure #3. are prepared. You will note that these details are schematic and not drawn completely to scale. However, the shop men and the structural draftsmen understand what is required.

Also, Girder Details — Figure #4. - End Portion of Riveted Girder - are prepared. Note that all of the drawings give complete information for identifying the shipping piece, the description and size of all the material which is to be assembled to form the shipping piece, the weight of each item and complete information required for fabrication.

The next three figures apply to the same shipping piece in the construction process. First — Figure #5. - The detail drawing for a Cantilever Girder. Next — Figure #6. - The fabricated Girder, and, finally — Figure #7. - the Erected Girder.

The fabricator's drawings are submitted to the customer's engineer for approval. The engineer's examination depends upon his personal preference. Some make a complete check, but most engineers are content with checking the general design, size of material used and the strength of the connections. The structural company is responsible for the correctness of the shop drawings, the Engineer's approval being merely the authority to proceed with the fabrication.

Shop and shipping bills are prepared from the approved detail drawings by the Operating Department. The shop bills contain a list of all the members on the contract with the material used to fabricate each member, the weight of each individual piece of material, the weight of the completed member, a list of the mill material with order item numbers showing the lengths from which the pieces are cut and the sections to be taken from stock material. The shop bill enables the shop to apply the proper material and gives the shop a list of all the members to fabricate to fulfill the contract.

The shipping bills contain a list of all the shipping pieces with descriptions and shipping marks, give the over-all dimensions of each member for purpose of identification, and include the figured weights. Actual scale weights are seldom used on structural steel contracts. Computed approximated weights are preferred.

Shop organization, equipment and the routine of handling work will vary for different operating departments. The usual plan is to have a large structural shop and a small auxiliary shop for fabricating light material and other buildings devoted to machine work, forge work and such other departments required for the plant production. All equipment, however, is located so that material can move progressively from the receiving yard to the shipping yard with the least handling of the material.

Various methods and devices are used for locating holes and cuts on the steel. Generally this is accomplished by the use of templets or by marking the steel directly from the drawings, without the use of templets — a process called "scratching." The templet is usually made of wood or cardboard or a combination of both to a full size scale.

During the time that the drawings are being prepared and the templets made, the material is received from the mills. As the material is unloaded, each item is checked against the mill orders. The material is sorted and piled on skids (Figure #8) for later consignment to the fabricating shop.

The first operation in the fabricating shop consists of marking the material and is called "laying out." The layer-out uses templets or scratches the steel. Also, he paints the assembly mark, the contract number, and other information on the steel. Before leaving the lay-out skids, usually the cuts and copes are made on the steel by the use of flame cutting.

The steel is then moved to the punches and drills. There are many special machines for punching and drilling.

After the detail pieces and main material of a member have been punched, the next operation is that of "fitting" or assembling of the various parts of a member for bolting, riveting or welding. All of the pieces are fitted by direct reference to the shop drawings. The main sections are identified by the description painted on the steel by the layer-out. Fitting up is probably the most difficult and responsible of any work in the structural shop.

Usually shop connections are either welded or riveted – bolting may be used on secondary connections. Three general classes of riveters are in use — stationary riveters, portable riveters and hand riveters. The method employed in driving rivets is determined by the size of the member and the accessibility for riveting. Virtually all welding in building construction is performed manually by the shielded metal arc process.

The next operation is to clean the fabricated members. Scrapers, brushes, shot blasting, flame cleaning or chemical baths may be used to remove dirt, scale, rust and foreign matter. If the steel is to be encased in concrete in the structure, the steel may be shipped unpainted since concrete adheres better to unpainted steel. Many types of paint are applied to steel. Steel which is used to support electrical equipment is often galvanized. Galvanizing is a process of coating steel with zinc spelter to resist corrosion.

Figure #9. is a general view of a fabricating shop. In the foreground is the lay-out area followed by the punches, fitting area and at the far end are the painting skids.

The fabricated steel is transferred from the shop to the shipping yard for dispatching to the field for erection. Figure #10. shows part of the shipping yard at Lehigh Structural Steel Co. in Allentown, Penna. Your eyes do not deceive you. The craneway in the foreground is curved. In order to move the steel directly from the shop thru the bridge arch an "S" curve craneway was designed. The crane which you see travels on a curve to right, a curve to left, or a straight track.

All through the fabrication process the matter of inspection to maintain accuracy and quality is very important. The structural companies have their own inspectors as a safeguard against errors. The correction of errors in the field is a very expensive matter. In addition, purchasers of structural steel usually employ outside inspectors to see that specifications and plans are adhered to in the rolling and fabrication.

On special contracts the engineer may require special inspection or testing. Figure #11. shows the arrangement for testing welded roof trusses. By using hydraulic jacks between a pair of trusses, the top truss being inverted, 150% of the design loads was applied to the trusses. The observed center deflections of the trusses checked with the calculated deflections and the original joint designs were adopted without alteration. As a matter of fact, the same trusses which you see under test are now in service in the completed building.

Figure #12. shows the detail of the joint at the column and the bottom chord of the truss. Figure #13. shows one of the bottom chord panel points.

The last department to physically handle the steel is the erection department. The erectors are the ones who put on a spectacular show for the sidewalk superintendents. Erectors have a choice of a large variety of hoisting equipment. By using the hoisting equipment and following the drawings prepared by the Drafting Department, the fabricated pieces are placed in their assigned places in the structure. The members are finally bolted, riveted or welded in position.

In recent years the size and use of truck cranes has been greatly increased. Twelve story structures have been erected by truck cranes working from the ground level. Figure #14. shows the erection of the steel in progress for a power house addition. The crane in the photo has 160' of boom. All of the steel was placed by the crawler crane working from the ground.

Now, I would like to show you a few photos of structural steel structures which have distinguishing features.

Figure #15. shows welded rigid frames in the Grit Chamber of the Owls Head Sewage Disposal Plant in New York City. As a sewage disposal plant, this project has many novel features. The rigid frames in the photo span 66', have a 23' rise and weigh 6 1/2 tons each. The column section is 20" deep at the base, the knee is 4'-9" deep and the beam section is a 30WF172. The knee and column web is 1/2" plate and each flange at the knee is composed of a 16 x 1-1/8 plate and a 14 x 1-1/8 plate.

Figure #16. is a photo of the base of the galvanized self-supported WOR-TV Tower in North Bergen, New Jersey. The four leg members are each composed of 4 - 8 x 8 x 1-1/8 angles. The legs are 96' centers at the base. Splices in the legs are made with ribbed bolts, other connections use ordinary bolts. Figure #17. is a view of the complete tower which rises 760' above the base and supports a 60' antenna. The Control House is located at the 550' level, at which level the legs are about 20' on centers.

The final group of figures are of a structure which is presently under construction. Figure #18. shows the raising of the east half of a camel-back truss which supports the roof and monorail cranes in an aircraft factory addition. The complete all welded truss spans 200' and has a rise of 40' at the mid-span. The bottom chord is 36' above floor level. The main members are 36WF sections with the webs parallel to the ground line. The tower on the right is used for erection purposes only. The half-truss you see weighs 37 tons. To the verticals of this truss are connected parallel chord trusses which have a span of 125'.

Figure #19. shows the west half of the camel-back truss in position. In Figure #20. the center tee is placed to complete the camel-back truss which has a total weight of 84 tons. The final structure provides a building which has a clear aisle of 200' with wall column centers at 125'.

Since the Chicago School introduced the rudiments of modern construction, long strides in material quality and fabrication techniques have been made. Forecasts for the future predict continued advancements. In order to provide a structure which has an enduring framework that is incombustible and has the economic factors of strength, compactness, adaptability, salvage and speed of erection, build with structural steel.

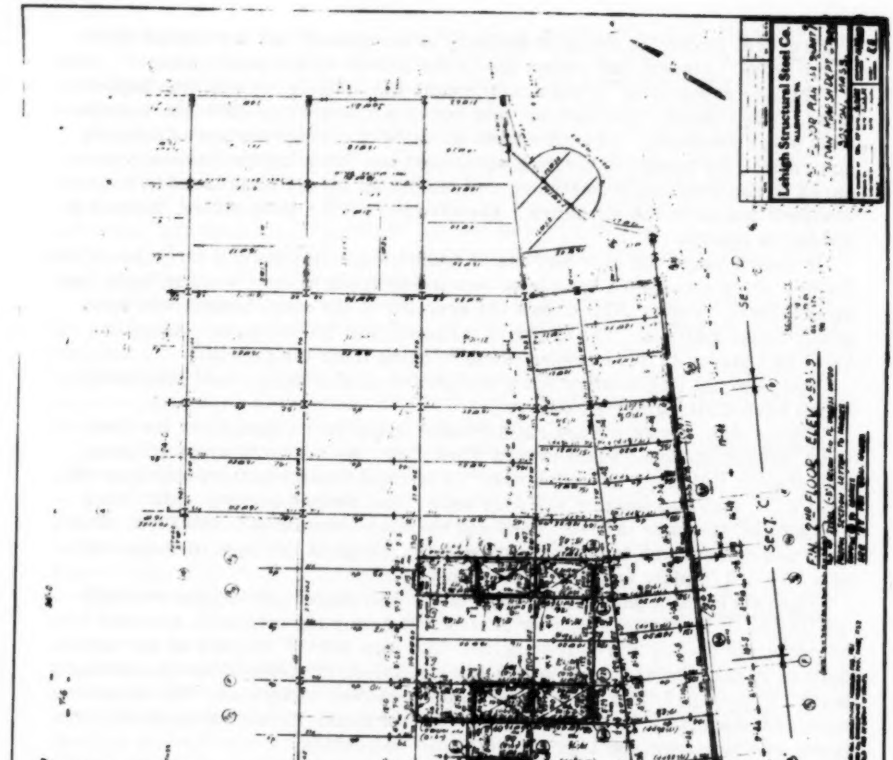

Lehigh Structural Steel Co.
SECT AA
SECT C
SECT B
SECT D
FIN. 2ND FLOOR ELEV. +53.9

FIG 1

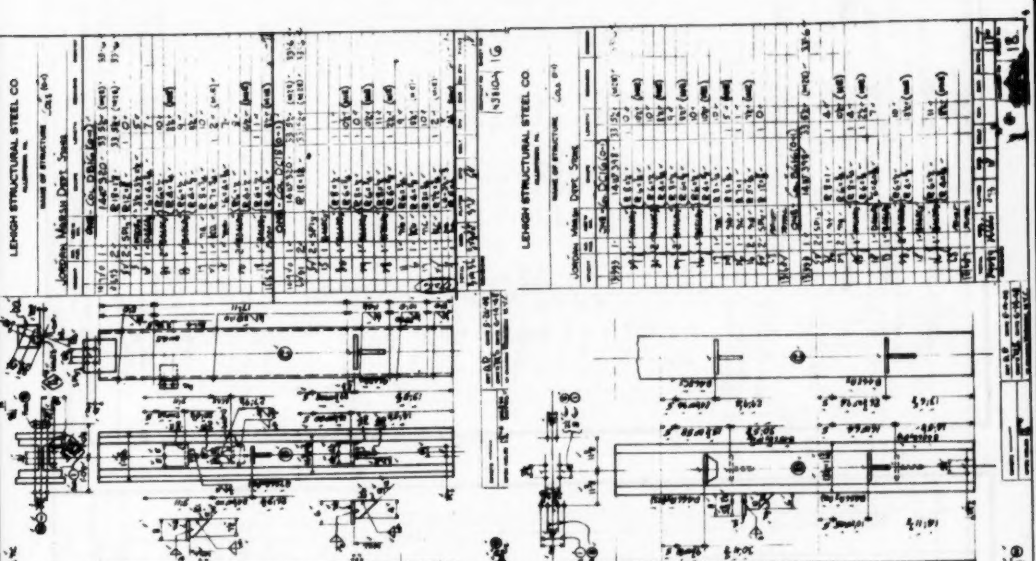


FIG 2

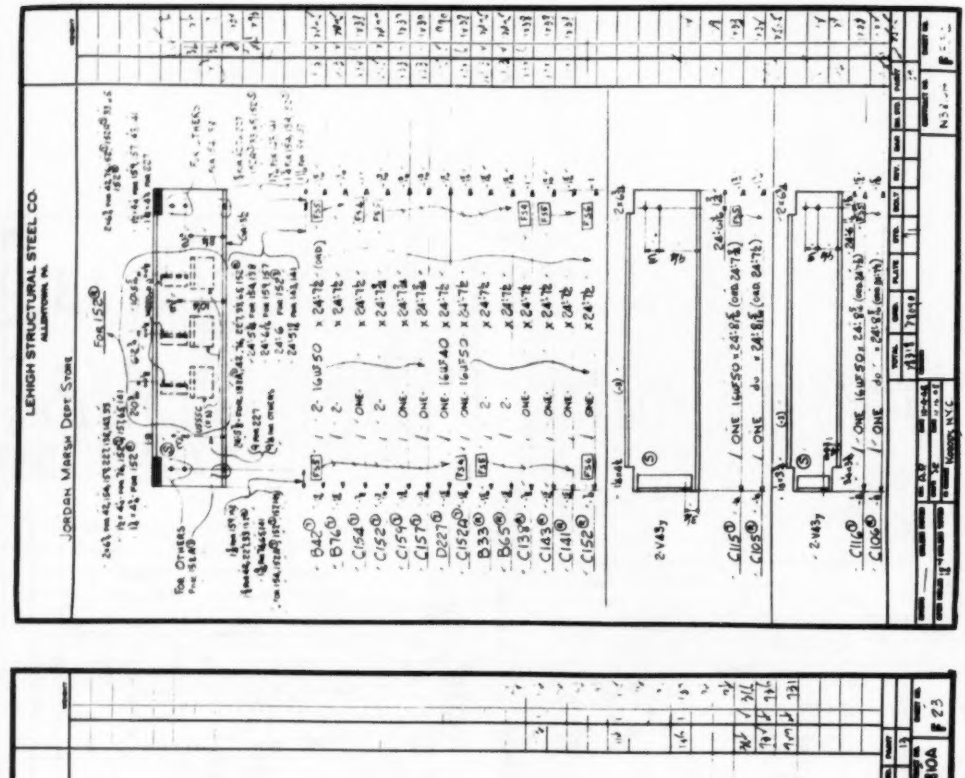

LEHIGH STRUCTURAL STEEL CO.
ALLENTOWN, PA.
JORDAN MARSH DEPT STORE
LEHIGH STRUCTURAL STEEL CO.
ALLENTOWN, PA.
JORDAN MARSH DEPT STORE
N3810A
F 23

FIG. 3

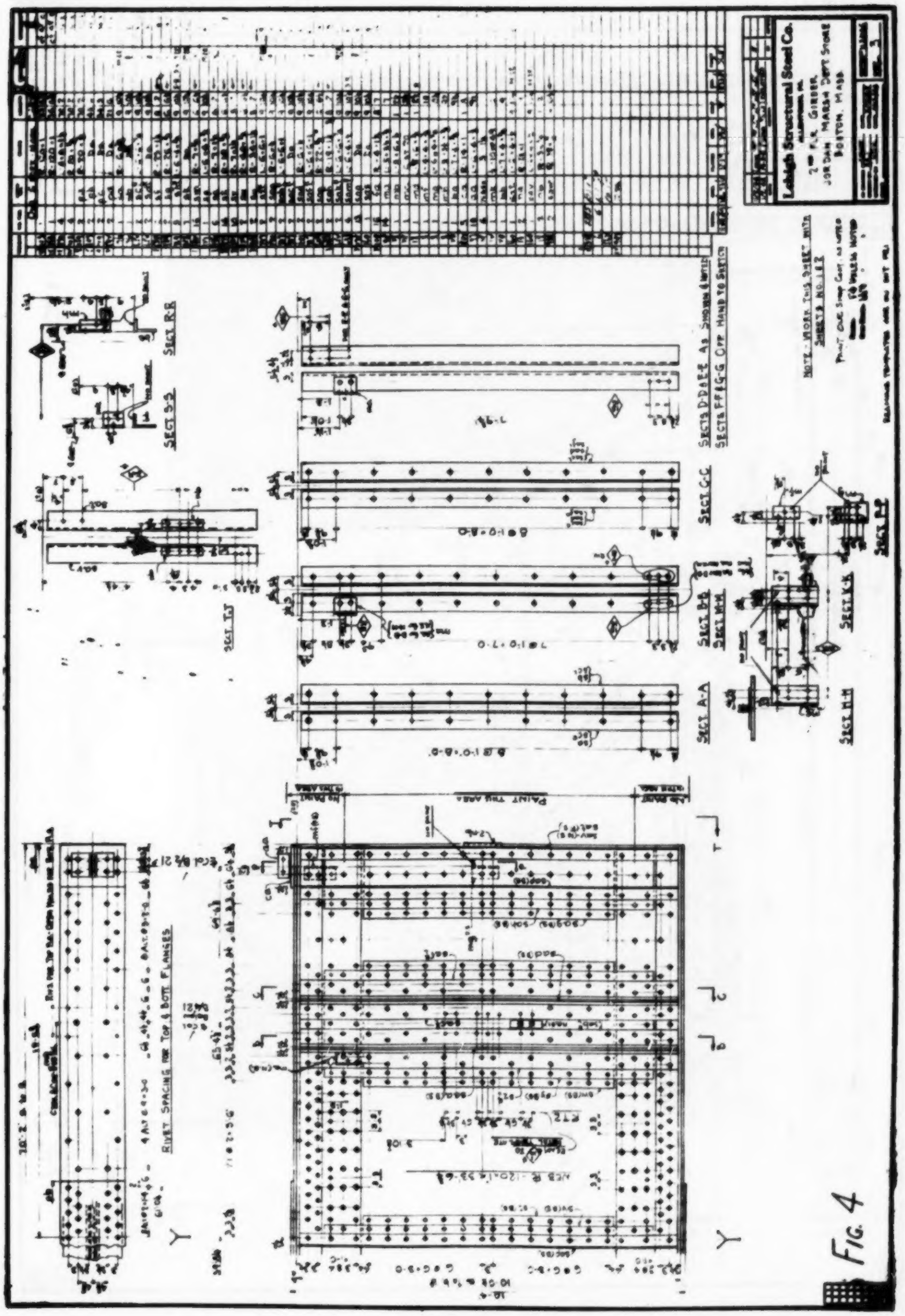
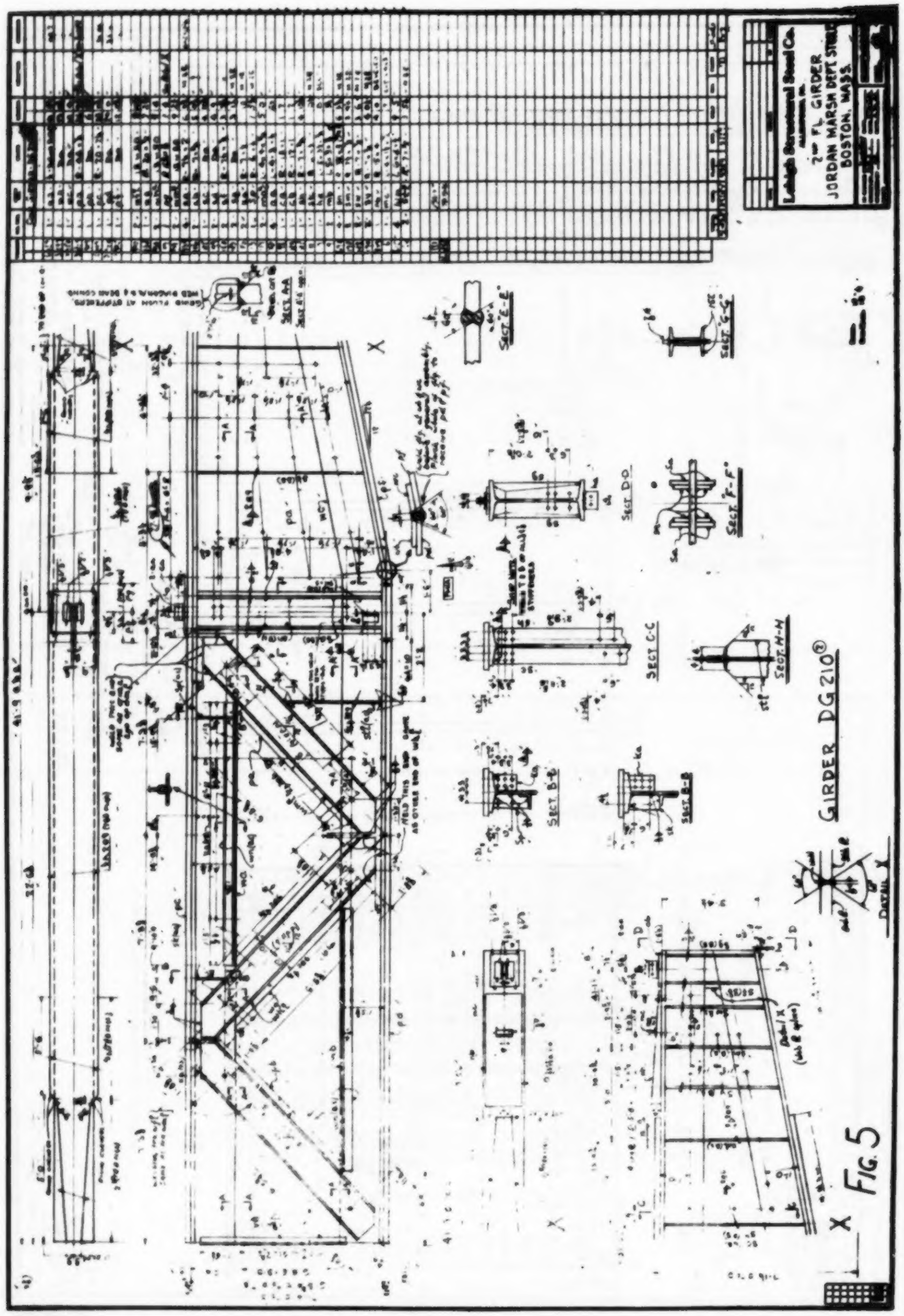

Lehigh Structural Steel Co.
2nd Flr. Girder
Jordan Marsh Dept Store
Boston, Mass
Rivet Spacing for Top & Bott Flanges
Sect A-A
Sect C-C
Sect H-H
Sect K-K

Fig. 4


Lehigh Structural Steel Co.
2nd FL. GIRDER
JORDAN MARSH DEPT. STORE
BOSTON, MASS.
GIRDER DG210
FIG. 5

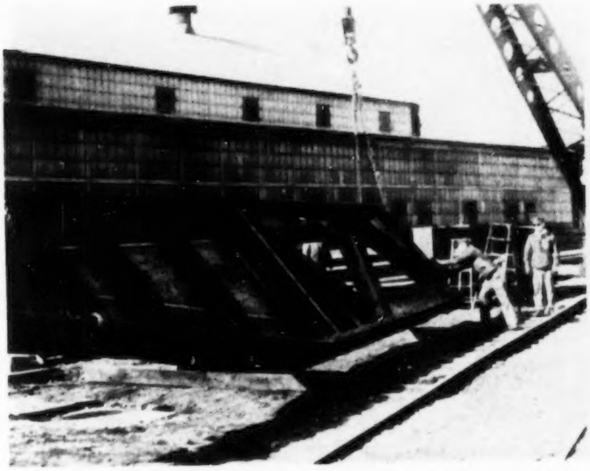


Fig. 6

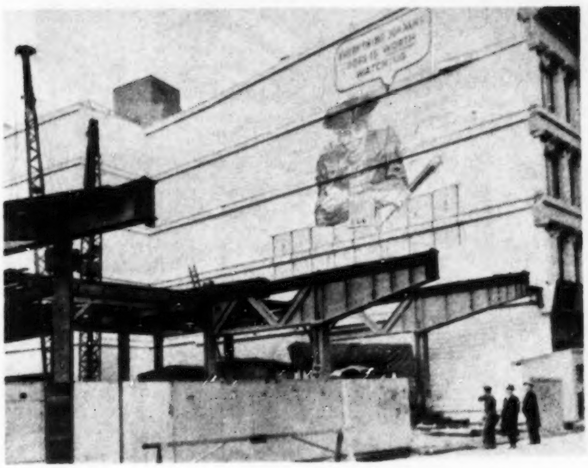


Fig. 7

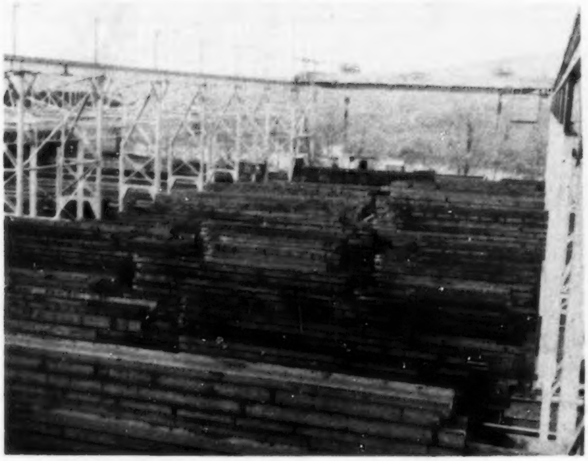


Fig. 8

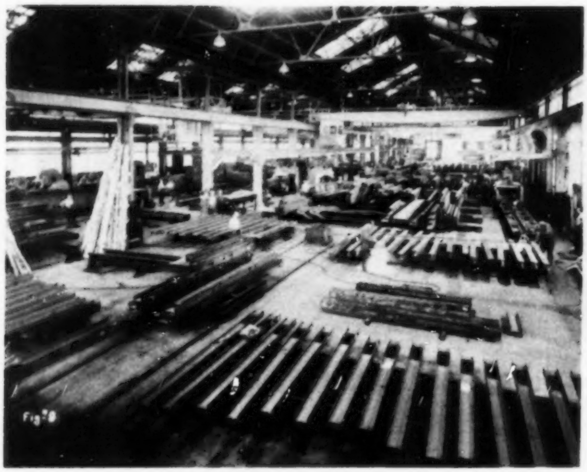
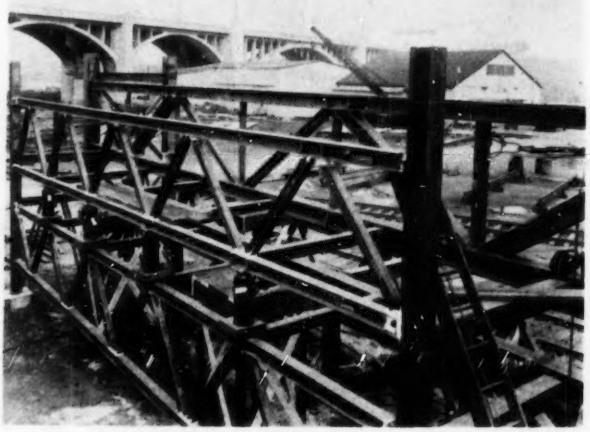
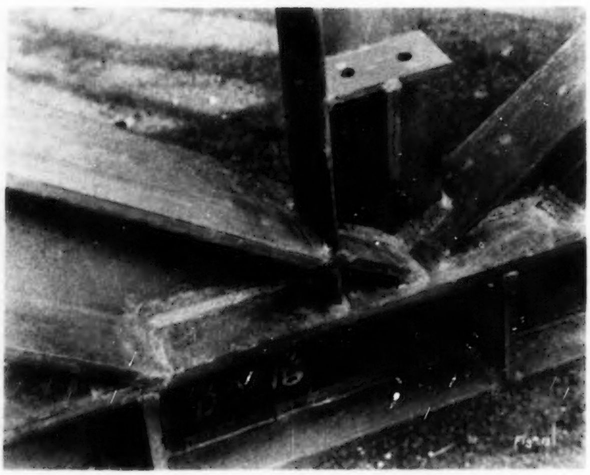


Fig. 10





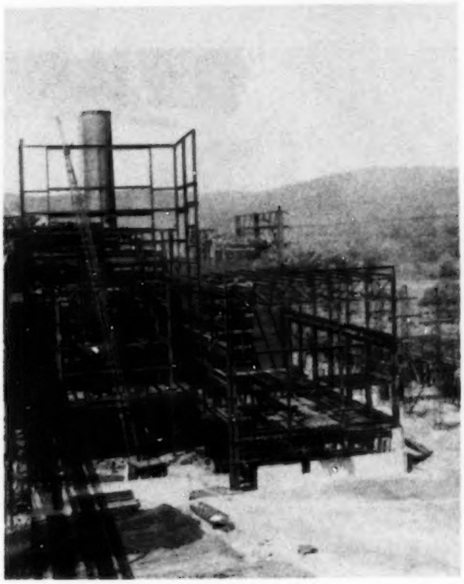


Fig. 14

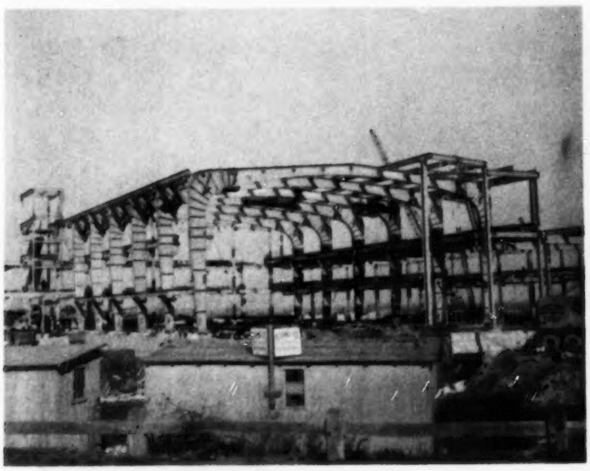


Fig. 15

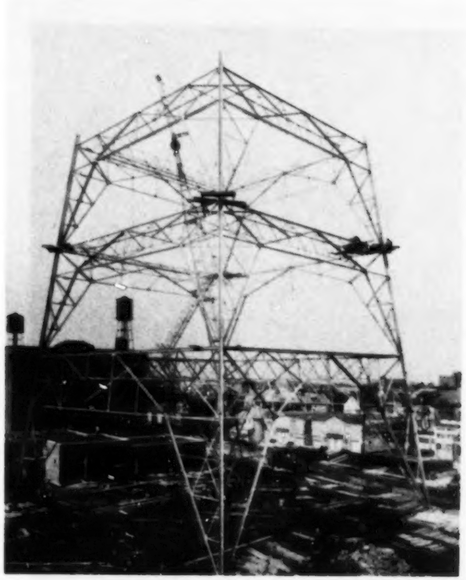


Fig. 16

Fig. 17

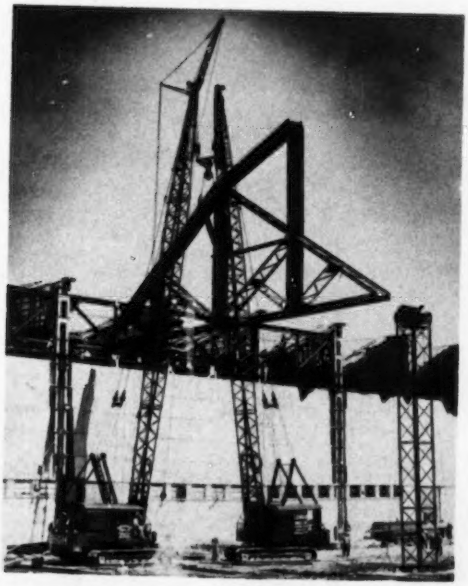


Fig. 18

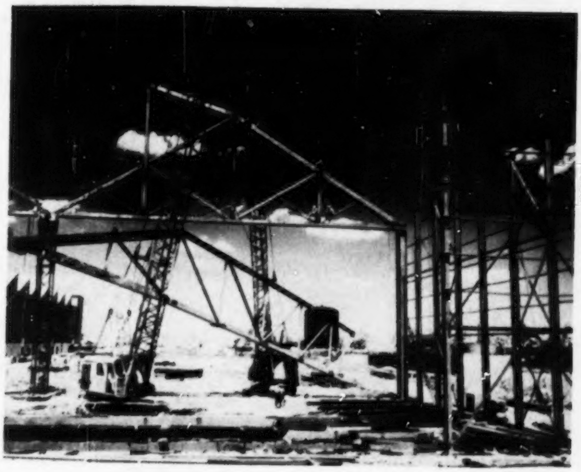


Fig. 19

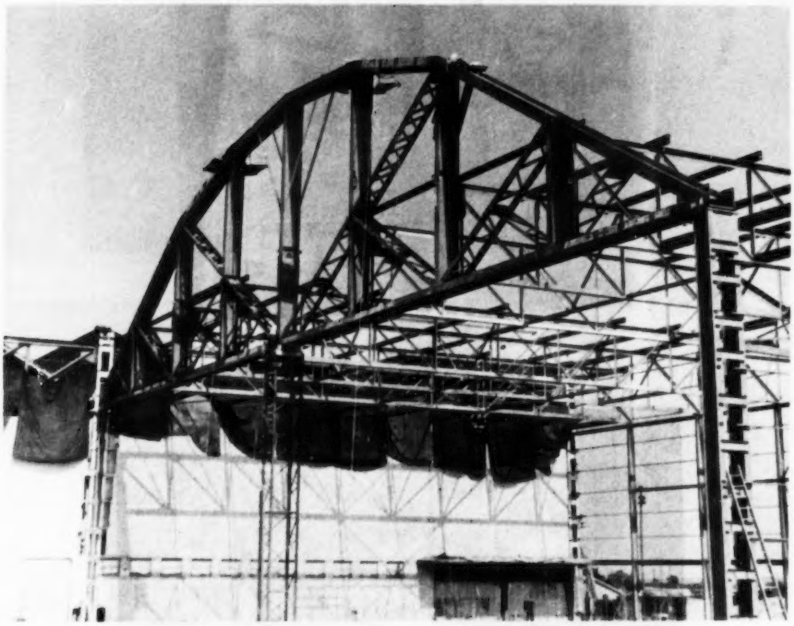


Fig. 20